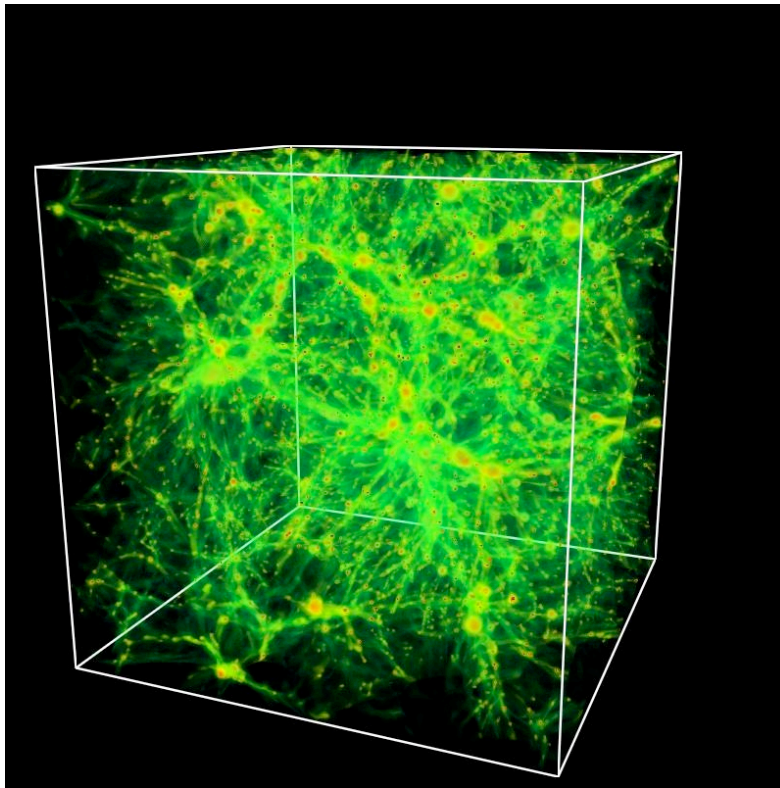


**Comparing predictions of a Warm Hot
Intergalactic Medium (WHIM) with XMM-
Newton observations of the cluster soft
excess**

Jonathan Mittaz (UAH)

Material $T \sim 10^{5-7}$ K see in models of large scale structure – the Warm Hot Intergalactic Medium (WHIM)



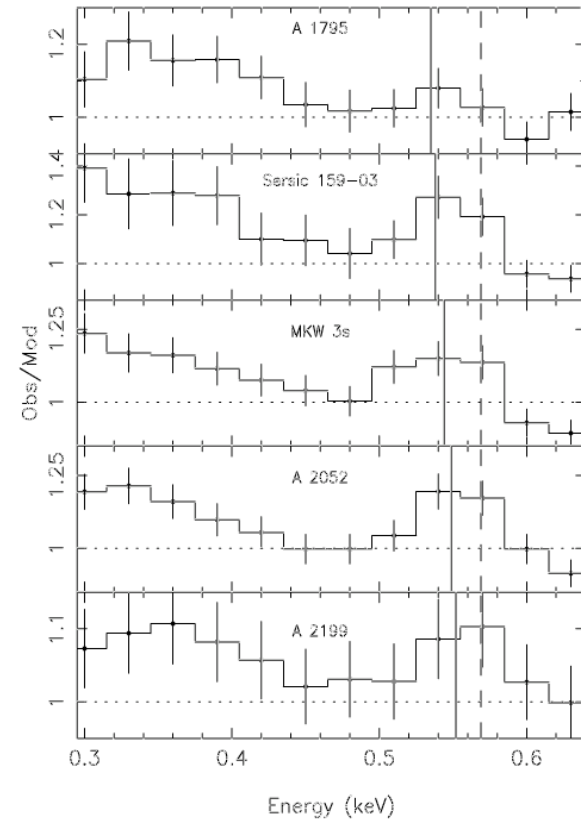
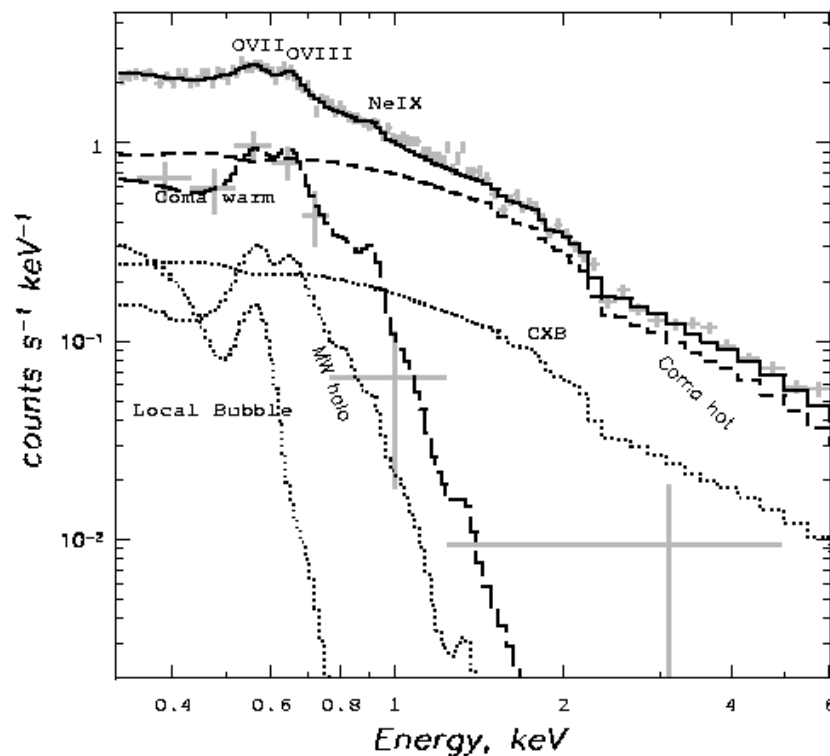
Filaments of material between clusters – contain up to 40% of the baryons in the Universe (e.g. Cen & Ostriker 1999)

Has it been seen?

Perhaps in the cluster soft excess

Cluster soft excess shows characteristics of the WHIM near the 'nodes'

- 1) Thermal emission with $T \sim \text{few } 10^6 \text{ K}$
- 2) Increases in importance on the outskirts of clusters

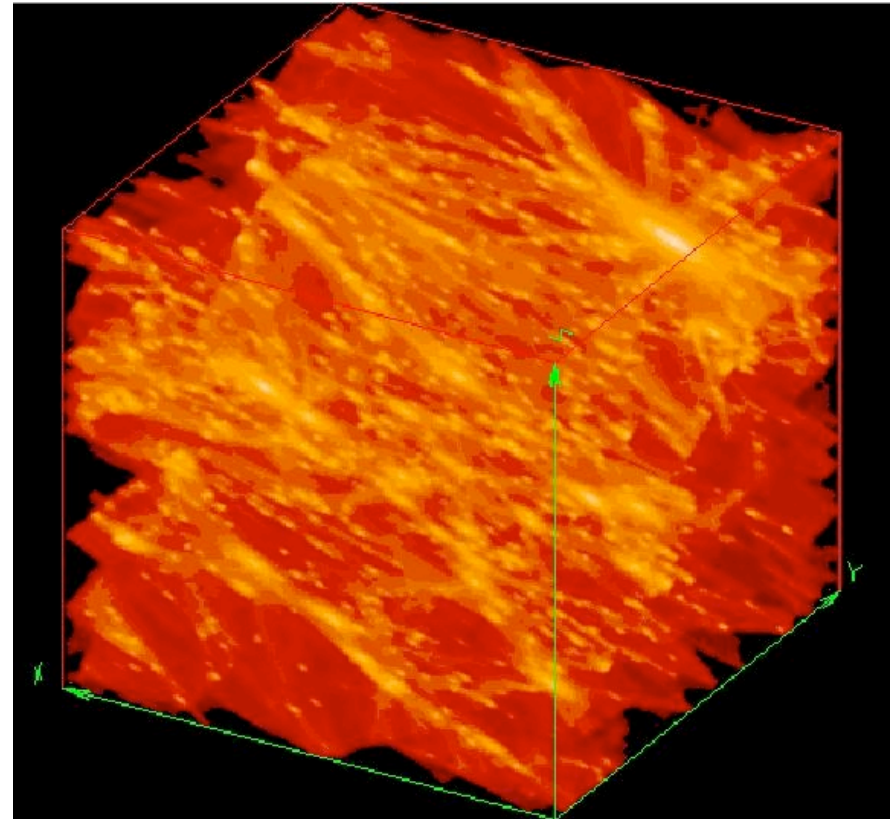


WHIM also solves some problems with thermal soft excess model.

BUT: Do models give rise to a soft excess?

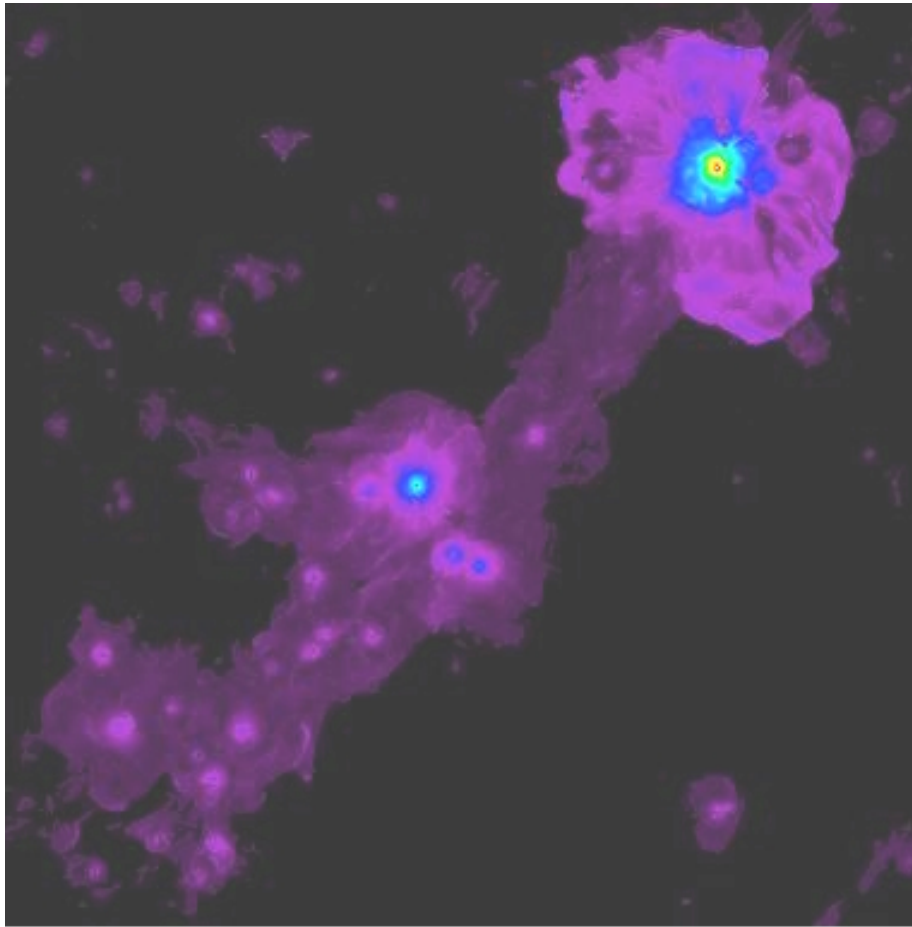
Preliminary comparison with observations of a simulation from Renyue Cen for $z = 0$

- 3 data cubes containing temperature, density, abundance
- Cube volume $25 h^{-1} \text{ Mpc}$ in 768^3 cells
- Parameters $\Omega_M=0.3$, $\Omega_\Lambda=0.7$, $\Omega_b h^2=0.017$, $h=0.67$



Density map from a simulation

Simulation shows wide range of temperatures:



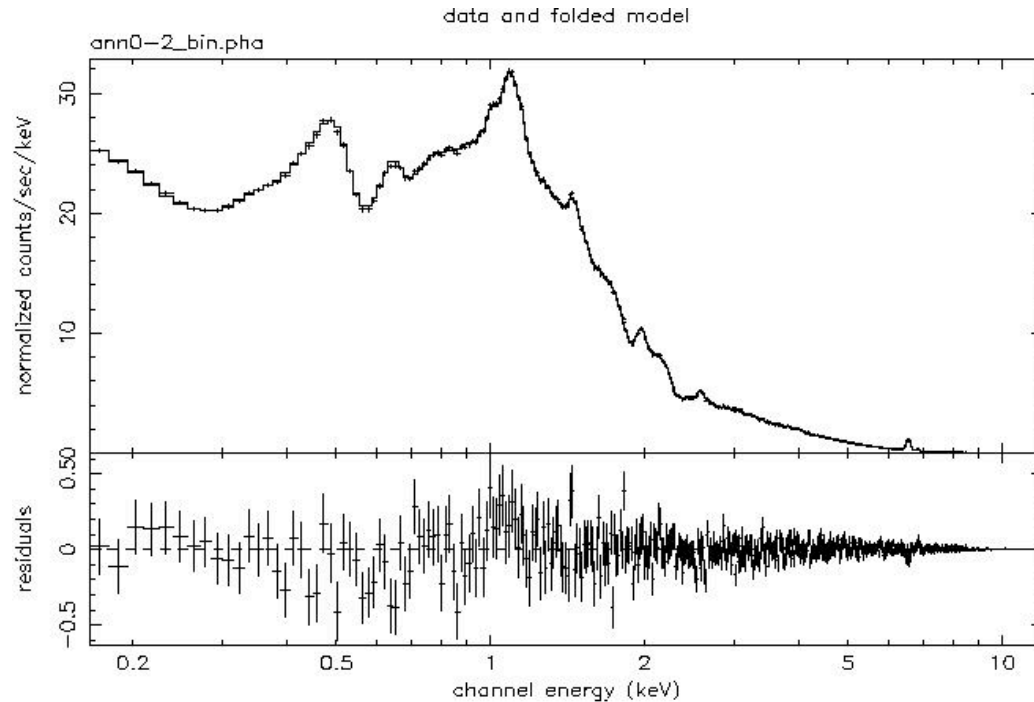
0 5.6
Emission weighted temperature map

Image shows range 0.08– 5.6 keV

Low Temperature structures
0.1-0.4 keV (in purple) –
typical temperatures of soft
excess

High temperature structure
top right – cluster candidate

From simulation we have generated XMM spectra



- Assumed Galactic $N_H = 9 \times 10^{19} \text{ cm}^{-2}$, $z = 0.02$
- Exposure time 50 ksec
- Added astrophysical background (Lumb et al. 2002)
- Added noise and spectrum grouped to minimum 25 counts/bin

0-2 cells (0-4 arcmin, central 100kpc)

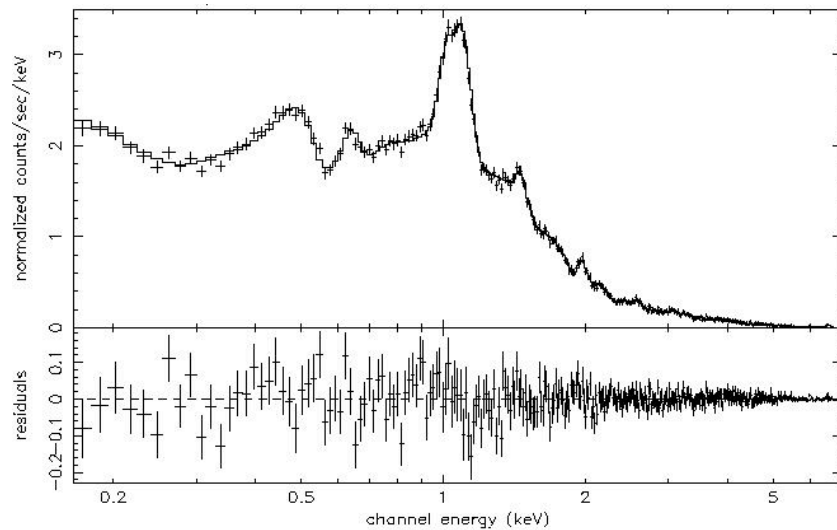
Best fit temperature : 4.7 keV

Best fit abundance : 0.5

Single temperature is a very good fit to data

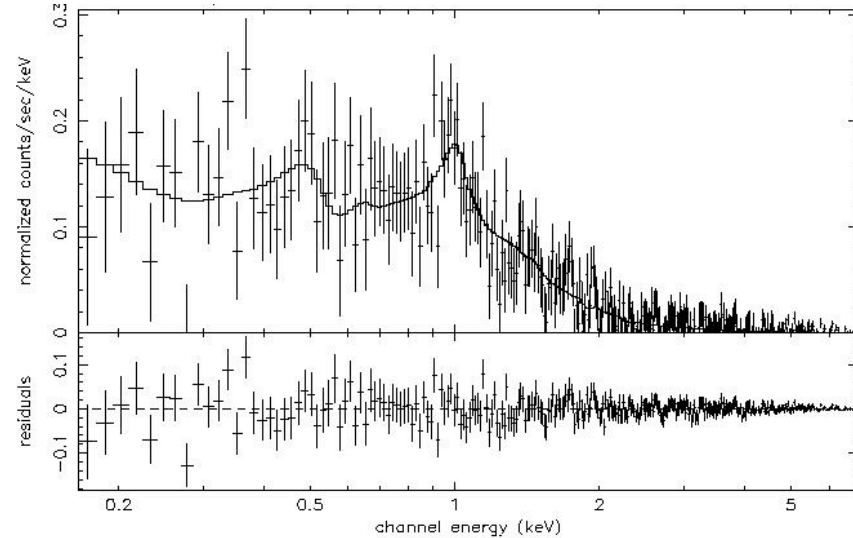
Outer annuli show the same effect

22-27 arcmin (580-680kpc)



Temperature : 2.27 keV
Abundance : 0.29

45-49 arcmin (1.17-1.26 Mpc)

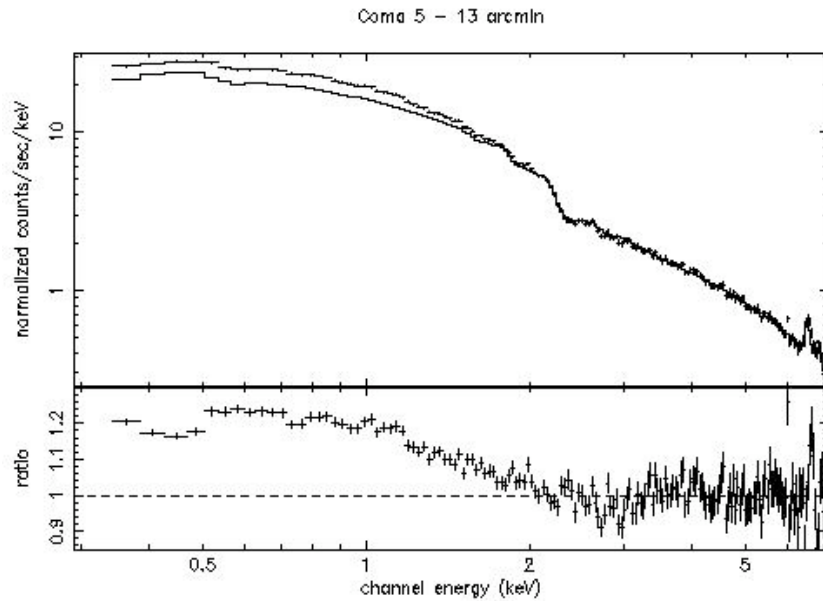


Temperature : 1.25 keV
Abundance : 0.06

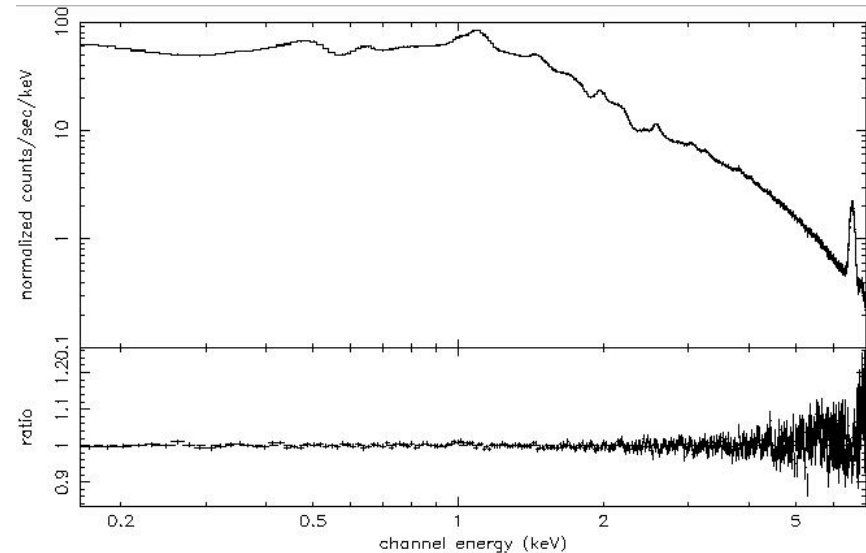
And no evidence for a soft excess!

Comparison with observations

Compare simulation with Coma cluster observations

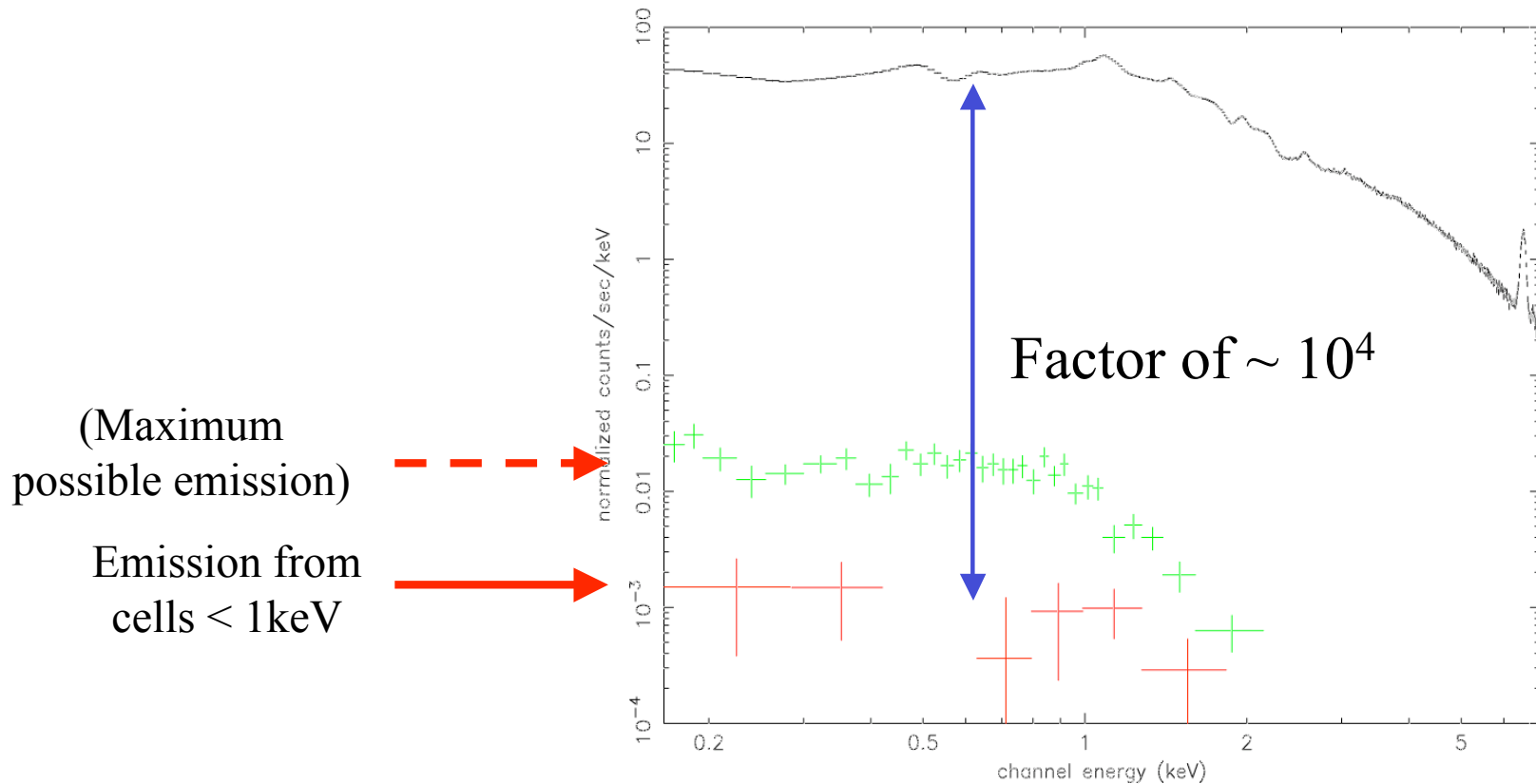


Coma spectrum 5-13 arcmin
(Nevalainen et al. 2002)



Simulated spectrum showing no
soft excess

Low temperature component extremely weak



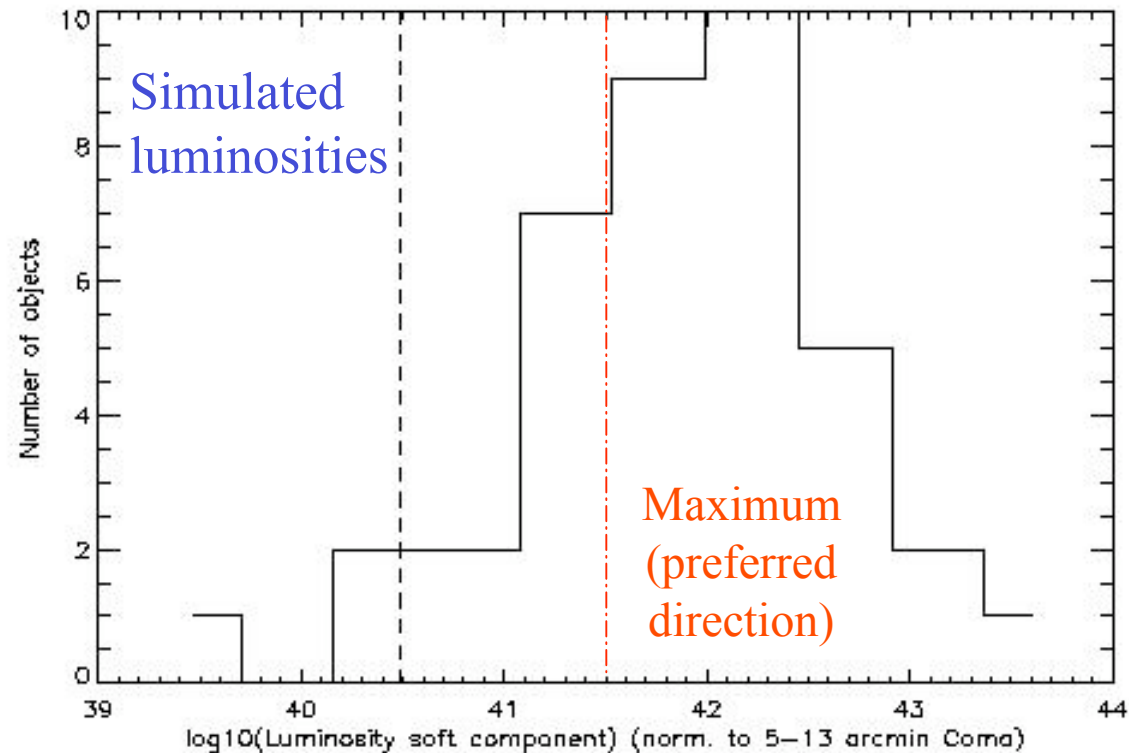
Comparing Luminosities		Simulated	Observed
	Hot component	8×10^{44}	2×10^{44}
	Warm component	3×10^{40}	3×10^{43}

Simulated hot component \sim agreement

Simulated warm component much fainter than observations

This seems generally to be true:

Compared with $> 1\sigma$ soft excesses observed with ROSAT
(Bonamente et al. 2002)



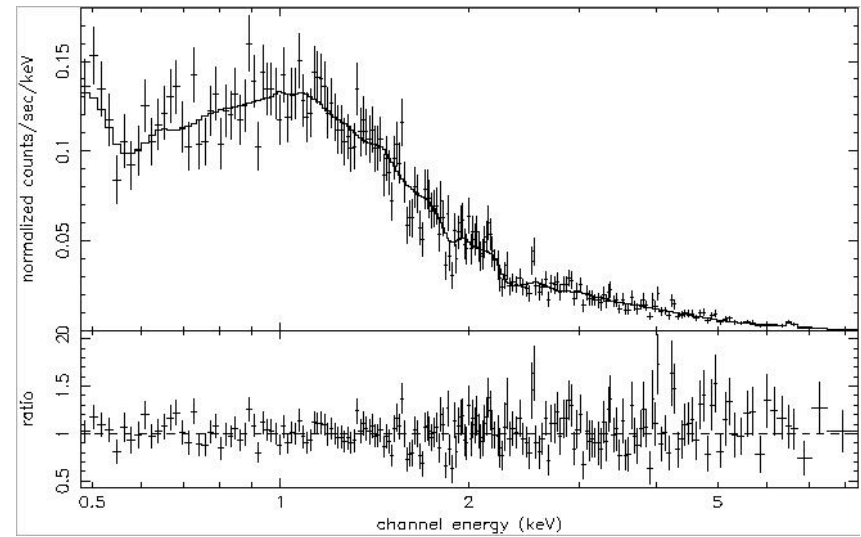
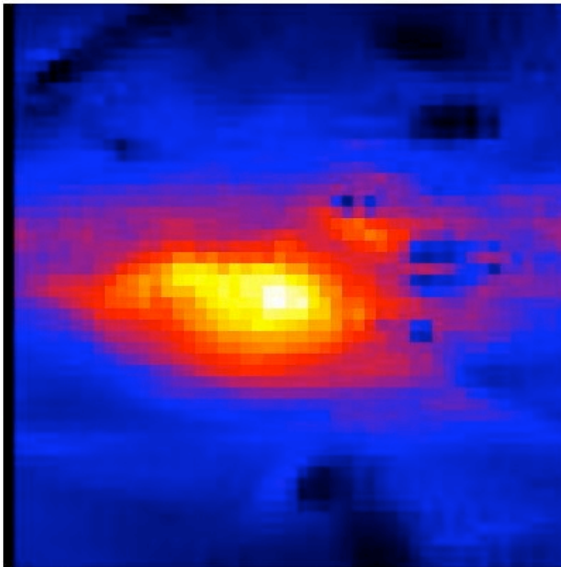
Generally no strong source of soft excess at centre of simulated cluster (max possible fraction explained by model $\sim 30\%$)

CONCLUSION

From studying this one simulation much of the soft excess seen in clusters *cannot* be explained by the currently simulated WHIM filaments. But:

1. Note that the soft excess is not seen in all clusters (e.g. 5/14 Kaastra et al. 2003) – is there some environmental difference (superclustering Kaastra et al. 2003)?
2. Soft excess at or near centre of clusters is strong + weak or absent line emission – some other mechanism (non-thermal?).
3. Only one structure + one simulation studied in detail – need to look at wider range of simulated clusters from different models. Preliminary work suggest same problem exists (D. Nagai private communication + LCA simulated cluster sample). Not enough resolution? Missing physics?

No apparent soft excess seen in one available cluster in the LCA simulated cluster archive

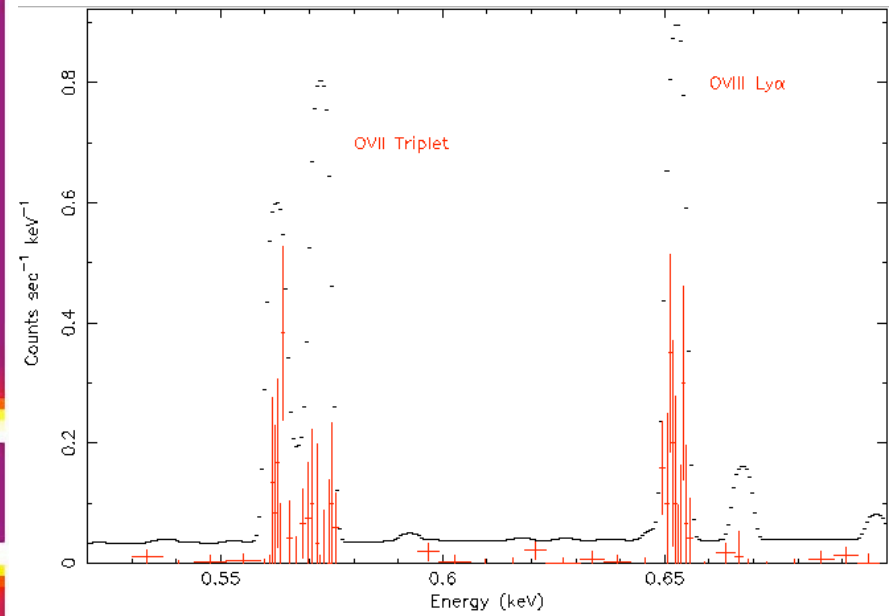
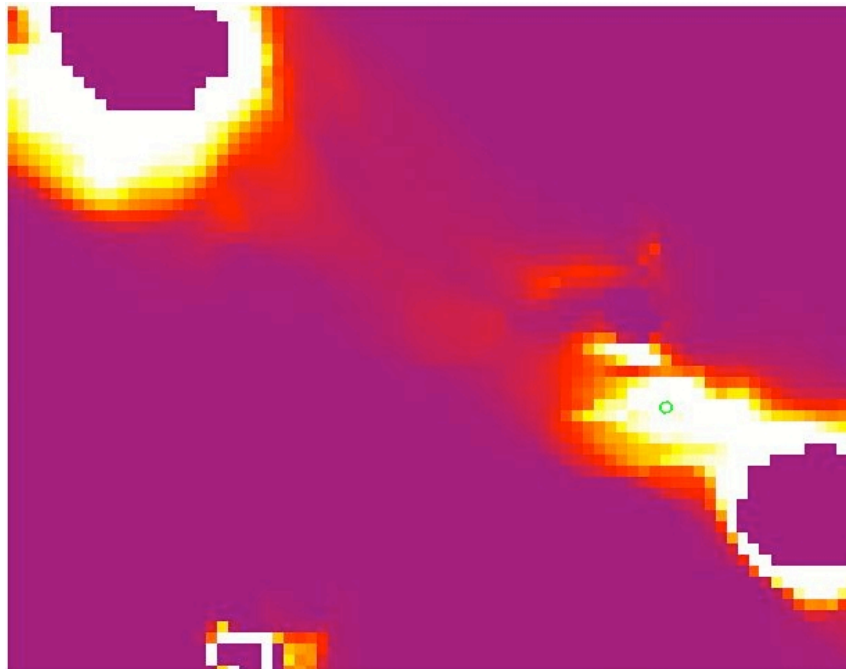


CONCLUSION

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3. Only one structure + one simulation studied in detail – need to look at wider range of simulated clusters from different model.
4. Constellation-X will have no trouble seeing soft excess, but seeing the WHIM at $z \sim 0$ will be hard according to these simulations.

Simulation of WHIM material. Weak signal in 10^5 seconds



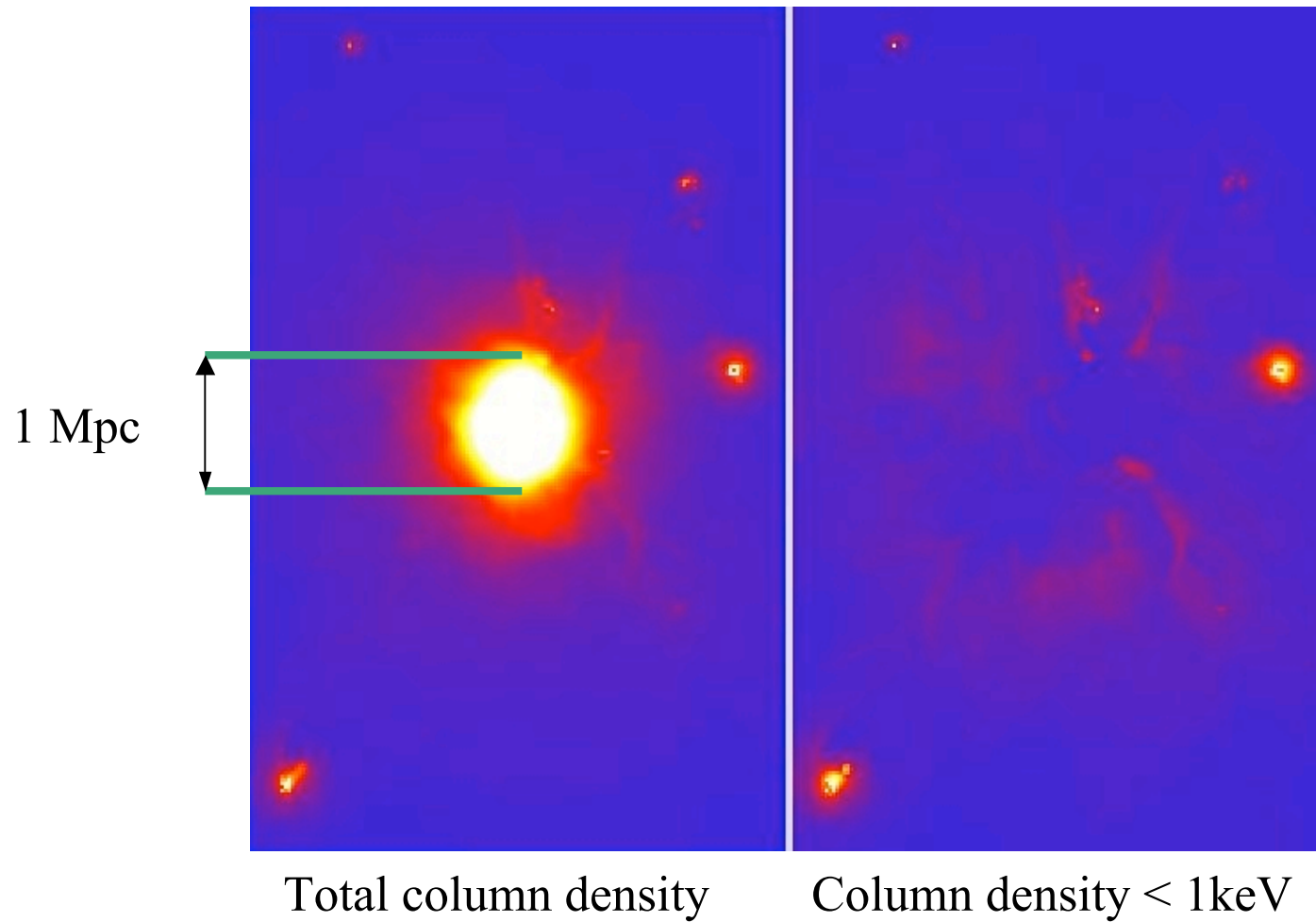
CONCLUSION

From studying this one simulation much of the soft excess seen in clusters *cannot* be explained by WHIM filaments.

But:

1. Note that the soft excess is not seen in all clusters (e.g. 5/14 Kaastra et al. 2003) – is there some environmental difference or some physical process that is missing from this simulation (superclustering, Kaastra et al. 2003)?
2. Soft excess at or near centre of clusters is strong + weak or absent line emission – some other mechanism (non-thermal?).
3. Only one structure + one simulation studied in detail – need to look at wider range of simulated clusters from different model.
4. Constellation-X will have no trouble seeing soft excess, but seeing the WHIM at $z \sim 0$ will be hard

Just not enough low temperature material:



Column density of low temperature components is much less than that of the hot component at the cluster